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(54) **THREE DIMENSIONAL (3D) TRANSVERSE OSCILLATION VECTOR VELOCITY ULTRASOUND IMAGING**

ULTRASCHALLBILDGEBUNG VON 3D-VEKTORGESCHWINDIGKEIT MITTELS TRANSVERSALER OSZILLATION

IMAGERIE TRIDIMENSIONNELLE (3D) ULTRASONORE D'ESTIMATION DE LA VITESSE VECTORIELLE TRANSVERSALE D'OSCILLATION

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Description

TECHNICAL FIELD

[0001] The following generally relates to ultrasound imaging and more particularly to three dimensional (3D) transverse oscillation vector velocity ultrasound imaging which can be used to estimate the spatial velocity components (depth, transverse and elevation) of blood flow velocity and/or moving tissue structures.

BACKGROUND

[0002] Ultrasound imaging provides useful information about the interior characteristics of an object or subject such as a human or animal patient. In one instance, an ultrasound scanner has been used to estimate blood flow velocity and generate one or more images of the interior characteristics with the estimated blood velocity superimposed there over.

[0003] With conventional ultrasound imaging blood flow velocity estimation, a pulse-echo field only oscillates in the axial direction along the axis of the ultrasound beam. This is illustrated in Figure 1 in which an ultrasound beam 102 propagates along a z-axis 104 and only the axial velocity component (vz) 106 along the z-axis or depth can be estimated; the transverse velocity components vx 108 and vy 110 cannot be estimated. Blood scatterers passing through the field of interest will produce a signal with a frequency component proportional to the axial velocity. The basic mechanism that allows the traditional estimation of axial velocities is the oscillations in the transmitted pulse.

[0004] The transverse oscillation (TO) blood velocity estimation approach has been used to estimate vz and vx. Using the same basic mechanism noted above, a transverse oscillation is introduced in the ultrasound field, and this oscillation generates received signals that depend on the transverse oscillation. The basic idea is to create a double-oscillating pulse-echo field using a one dimensional (1D) transducer array. This had been accomplished by using the same transmit beam as used in conventional velocity estimation and particularly predetermined apodization profiles in receive. Suitable apodization functions are discussed in J. A. Jensen and P. Munk, "A New Method for Estimation of Velocity Vectors," IEEE Trans. Ultrason., Ferroelec., Freq. Contr., vol. 45, pp. 837-851, 1998, and J. Udesen and J. A. Jensen, "Investigation of Transverse Oscillation Method," IEEE Trans. Ultrason., Ferroelec., Freq. Contr., vol. 53, pp. 959-971, 2006.

[0005] Figure 2 shows an example of the TO approach for estimating vz and vx. In this example, the transverse oscillations are created in receive, and two lines are beamformed in parallel to get the spatial lateral in-phase (I) and quadrature (Q) components. The spatial IQ samples, r_{IQ}, are obtained by $r_{IQ}(t) = r_I(t) + jr_Q(t)$, where r_I and r_Q are the samples at time t from the left and right beam, respectively. Along with the two TO lines, a center line can be beamformed for conventional axial or depth velocity estimation. Using the Fraunhofer approximation, the relation between the lateral spatial wavelength and the apodization function is: $\lambda_x = 2\lambda_z Z_{0/}d$, where d is the distance between the two peaks in the apodization function, z_0 is depth, and λ_z is the axial wavelength.

[0006] From the above apodization function, the lateral wavelength (λ_x) increases as the depth (z_0) increases, if the apodization function (d) is kept constant. To keep a constant lateral wavelength (λ_x), the aperture must expand with depth (z_0). Using a phased array, the width is often limited, so instead the spacing between the two beamformed lines can be increased through depth. Keeping the apodization function fixed, the two lines can be beamformed with a fixed angle. Using the tangent-relation, the angle, θ, between the two lines can be derived as $\theta/2 = \arctan((\lambda_x / 8) / z_0) = \arctan(\lambda_z / 4d)$.

[0007] If r_{IQ} is the spatial IQ signal, then the corresponding temporal IQ signal can be referred to as $r_{IQ,h}$, and two new signals, r_1 and r_2, can be generated $r_1(k) = r_{IQ}(k) + jr_{IQ,h}(k)$ and $r_2(k) = r_{IQ}(k) - jr_{IQ,h}(k)$, where k denotes discrete samples. The transverse velocity (vx) can then be calculated by:

$$\mathrm{vx} = \left(\frac{\lambda_x}{2\pi 2kT_{prf}}\right)\arctan\left(\frac{\Im\{R_1(k)\}\Re\{R_2(k)\} + \Im\{R_2(k)\}\Re\{R_1(k)\}}{\Re\{R_1(k)\}\Re\{R_2(k)\} - \Im\{R_2(k)\}\Im\{R_1(k)\}}\right),$$

where T_{prf} is the time between two pulses, $R_1(k)$ is the complex lag k autocorrelation value for $r_1(k)$, and $R_2(k)$ is the complex lag k autocorrelation value for $r_2(k)$. The complex autocorrelation is estimated over N shots, and is typically spatially averaged over a pulse length.

[0008] Three dimensional (3D) velocity approaches for estimating vz, vx and vy are discussed in M. D. Fox, "Multiple crossed-beam ultrasound Doppler velocimetry," IEEE Trans. Son. Ultrason., vol. SU-25, pp. 281-286, 1978, and G. E. Trahey, J. W. Allison, and O. T. von Ramm, "Angle independent ultrasonic detection of blood flow," IEEE Trans. Biomed. Eng., vol. BME-34, pp. 965-967, 1987. Unfortunately, Fox uses a multibeam approach that requires trigonometry to determine velocity, and Trahey uses speckle tracking (normalized cross-correlation) to determine a three dimensional (3D) velocity vector from the entire acquired 3D volume of data.

[0009] US-A-6148224 discloses apparatus and method for determining movements and velocities of moving objects, particularly in ultrasound imaging. A velocity of an object transverse to the direction of propagation of an ultrasound wave can be detected by applying a field which oscillates spatially in one or two transverse directions with respect to the axial or propagation direction.

[0010] US-B-6527717 discloses a medical diagnostic ultrasound system and method for tissue motion analysis in which estimates of motion from ultrasound data are improved. This is achieved by obtaining Doppler velocity estimates and compensating or correcting for transducer motion in one-, two- or three-dimensions to isolate better localized tissue contractions and/or expansions.

[0011] US-A-5201313 discloses an ultrasonic flowmeter in which a sampling device samples reception signals from a target, the sampled signals being processed to perform moving target indication based on time since transmission. A first one-dimension Fourier transform device transforms the moving target indication in the directions of the reception beams. As second Fourier transform device is used to process the output from the first Fourier transform device to evaluate the lateral velocity and axial velocity of a moving target.

[0012] WO-A-00/68678 discloses a method and an apparatus for estimating the velocity vector of a remotely sensed object using ultrasound in which the movement of the object is determined by using transverse spatial oscillations for influencing the received signal, and, using an autocorrelation estimator for determining the velocity vector.

SUMMARY

[0013] Aspects of the application address the above matters, and others. The invention is defined in the appended claims.

[0014] In one aspect, an ultrasound imaging system includes a transducer array with a two-dimensional array of transducer elements configured to transmit an ultrasound signal to traverse a field of view and to receive echoes from the field of view, transmit circuitry configured to generate a set of pulses for the transducer array so as to transmit the ultrasound signal to traverse the field of view, and receive circuitry configured to receive a two dimensional set of echoes produced in response to the ultrasound signal traversing structure in the field of view, the structure including flowing structure. A beamformer configured to beamform the echoes to produce beamformed data therefrom, and a velocity processor configured to process the beamformed data to determined velocity components therefrom. The beam former is further configured to beamform four lines of data from the two dimensional set of echoes derived from the same transmitted ultrasound signal and the same received set of two dimensional echoes, the four lines of data including a first pair of lines and a second pair of lines, and, the velocity processor is configured to separately determine a transverse velocity component from the first pair of lines and an elevation velocity component from the second pair of lines, the velocity components being determined based on the same transmitted ultrasound signal and the same received set of two dimensional echoes, and, to estimate the depth velocity component based on at least one of: the first pair of lines used to determine the transverse velocity component and the second pair of lines used to determine the elevation velocity component.

[0015] In another aspect, a method for determining velocity components from ultrasound echoes includes transmitting an ultrasound signal to traverse a field of view, and, receiving a two dimensional set of received echoes corresponding to a same transmit ultrasound signal. The method further comprises beamforming the receive echoes to produce beamformed data therefrom and processing the beamformed data to determine velocity components therefrom. The method further includes beamforming four lines of data from the two dimensional set of received echoes, the four lines of data including a first pair of lines and a second pair of lines and separately determining a transverse velocity component from the first pair of lines and an elevation velocity component from the second pair of lines. The method further includes estimating a depth velocity component based on at least one of: the first pair of lines used to determine the transverse velocity component and the second pair of lines used to determine the elevation velocity component.

[0016] In another aspect, a velocity processor includes a depth velocity processor, a transverse velocity processor, and an elevation velocity processor. The depth, transverse velocity and elevation velocity processors respectively generates signals indicative of a depth velocity component in a z direction along which a transmit ultrasound signal traverses, a transverse velocity component traversing a z-x plane, and an elevation velocity component traversing a z-y plane, based on a two dimensional set of echoes received in response to the same transmit ultrasound signal.

[0017] Those skilled in the art will recognize still other aspects of the present application upon reading and understanding the attached description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The application is illustrated by way of example and not limited by the figures of the accompanying drawings, in which like references indicate similar elements and in which:

Figure 1 illustrates a prior art approach to estimating flow and/or tissue velocity along the depth of the transmitted ultrasound signal;

Figure 2 illustrates a prior art approach to estimating flow and/or tissue velocity along the depth of the transmitted ultrasound signal and along a transverse direction;

Figure 3 schematically illustrates an example ultrasound imaging system in connection with a beamformer and velocity processor for determining velocity in depth, transverse and elevation directions;

Figure 4 schematically illustrates examples of the beamformer and velocity processor of Figure 3;

Figure 5 illustrates beamformed lines for producing data for determining velocity in depth, transverse and elevation directions,

Figure 6 illustrates a method; and

Figure 7 schematically illustrates a variation of the embodiment of Figure 4.

DETAILED DESCRIPTION

[0019] Initially referring to Figure 3, an example ultrasound imaging system 300 is illustrated.

[0020] A transducer array 302 includes a two dimensional (2D) array of transducer elements, which are configured to transmit ultrasound signals and receive echo signals. Examples of suitable 2D arrays include 32x32, 64x64, and/or other dimension arrays, including square and/or rectangular arrays. The array can be linear, curved, and/or otherwise shaped. The array can be fully populated or sparse and/or a combination hereof.

[0021] Transmit circuitry 304 generates a set of pulses that are conveyed to the transducer array 302. The set of pulses actuates a corresponding set of the transducer elements of the transducer array 304, causing the elements to transmit ultrasound signals into an examination or scan field of view. In the illustrated embodiment, transmit circuitry 304 generates a set of pulses which produce a transmit signal suitable at least for velocity imaging.

[0022] Receive circuitry 306 receives echoes generated in response to the transmitted ultrasound signals from the transducer 302. The echoes, generally, are a result of the interaction between the emitted ultrasound signals and the structure (e.g., flowing blood cells, organ cells, etc.) in the scan field of view.

[0023] A controller 308 controls one or more of the transmit circuitry 304 or receive circuitry 306. Such control can be based on available modes of operation (e.g., velocity flow, A-mode, B-mode, etc.) of the system 300. In addition, such control can be based on one or more signals indicative of input from a user via a user interface (UI) 310. The UI 310 may include one or more input devices (e.g., a button, a knob, a slider, a touch pad, etc.) and/or one or more output devices (e.g., a display screen, lights, a speaker, etc.).

[0024] A beamformer 312 processes the echoes, for example, by applying time delays, weighting on the channels, summing, and/or otherwise beamforming received echoes. As described in greater detail below, in one instance, the beamformer 312 includes a plurality of beamformers that simultaneously process the echoes and produce data for determining the three dimensional (3D) velocity components, vz (depth velocity), vx (transverse velocity) and vy (elevation velocity). The illustrated beamformer 312 also produces data for generating images in A-mode, B-mode, and/or other modes.

[0025] A velocity processor 314 processes the beamformed data output by the beamformer 312 output. This includes processing the beamformed data to determine one or more of the 3D velocity components, vz, vx or vy. As described in greater detail below, in one instance the velocity processor 314 individually and separately estimates vz, vx or vy based on a same transmission ultrasound signal and the corresponding two dimensional (2D) acquired data.

[0026] An image processor 316 also receives the beamformed data from the beamformer 312. For B-mode, the image processor 316 processes the data and generates a sequence of focused, coherent echo samples along focused scanlines of a scanplane. The image processor 316 may also be configured to process the scanlines to lower speckle and/or improve specular reflector delineation via spatial compounding and/or perform other processing such as FIR filtering, IIR filtering, etc.

[0027] A scan converter 318 scan converts the output of the image processor 316 to generate data for display, for example, by converting the data to the coordinate system of the display. The scan converter 318 can be configured to employ analog and/or digital scan converting techniques.

[0028] A rendering engine 320 visually presents one or more images and/or velocity information via a display monitor 322. Such presentation can be in an interactive graphical user interface (GUI), which allows the user to selectively rotate, scale, and/or manipulate the displayed data. Such interaction can be through a mouse or the like, and/or a keyboard or the like, touch-screen controls and/or the like, and/or other known and/or approach for interacting with the GUI.

[0029] It is to be appreciated that the beamformer 312 and/or the velocity processor 314 can be implemented via a processor executing one or more computer readable instructions encoded or embedded on computer readable storage medium such as physical memory. Such a processor can be part of the system 300 and/or a computing device remote from the system 300. Additionally or alternatively, the processor can execute at least one computer readable instructions carried by a carrier wave, a signal, or other non-computer readable storage medium such as a transitory medium.

[0030] Figures 4 and 5 illustrate a non-limiting example. Figure 4 depicts examples of the beamformer 312 and the velocity processor 314, and Figure 5 depicts the beamformed data used to determine the velocities vz, vx and/or vy. For this example, the transmit circuitry 304 (Figure 3) controls the transducer array 302 (Figure 3) so that a lateral width of the transmitted pulse is broad enough to cover the beamformed receive lines. This can be done using a high F-number, a focal depth further away than the depth of interest, plane waves, or other approach. The transverse oscillations are created in receive.

[0031] The beamformer 312 includes five (5) beamformers 402, 404, 406, 408 and 410. The beamformer 402 is configured to produce data for determining vz, the beamformers 404 and 406 are configured to produce data for determining vx, and beamformers 408 and 410 are configured to produce data for determining vy. The beamformers 404 and 406 have apodization peaks that are separated or spaced apart by a predetermined distance and simultaneously create the lines Ix and Qx in the z-x plane. The beamformers 408 and 410 have apodization peaks that are separated or spaced apart by a predetermined distance and simultaneously create the lines Iy and Qy in the z-y plane. The apodization of vx and vy is ninety degrees (90°) apart.

[0032] In this example, the lines Ix, Qx, Iy and Qy are beamformed based on a same fixed angle θ that corresponds to an increasing lateral wavelength. In another embodiment, the lines Ix and Qx and the lines Iy and Qy can be beamformed based on different fixed angles or a fixed distance between them. In this example, all five of the lines z, Ix, Qx, Iy and Qy are beamformed simultaneously. In another embodiment, all five of the lines z, Ix, Qx, Iy and Qy are not beamformed simultaneously. In yet another embodiment, the beamformer 312 includes more than five beamformers in which several velocity image lines are beamformed in parallel.

[0033] The velocity processor 314 includes a depth processor 412 that processes the data generated by the beamfomer 402 and estimates vz, a transverse processor 414 that processes the data generated by the beamfomers 404 and 406 and estimates vx, and an elevation processor 416 that processes the data generated by the beamfomers 408 and 410 and estimates vy. The depth processor 412 can use a conventional autocorrelation and/or other approach to estimate vz. The transverse processor 414 and the elevation processor 416 can use a transverse oscillation (TO) approach to determine vx and vy.

[0034] For example, from above, for vx, the Fraunhofer approximation can be used to determine the $\lambda_x = 2\lambda_z z_0/d$, where d is the distance between the two peaks in the apodization function, z_0 is depth, and λ_z is the axial wavelength. Alternatively, λ_x can be determined based on the simulated or measured pulse-echo field. The Fraunhofer approximation can similarly be used for vy in which the relation is $\lambda_y = 2\lambda_z z_0/d$. Using the tangent-relation, the angle between the two lines is $\theta/2 = \arctan((\lambda_y/8)/z_0) = \arctan(\lambda_y / 4d)$. Using the same constraints as used for vx, the elevation velocity (vy) can then be calculated by:

$$\mathrm{vy} = \left(\frac{\lambda_y}{2\pi 2kT_{prf}}\right)\arctan\left(\frac{\Im\{R_1(k)\}\Re\{R_2(k)\} + \Im\{R_2(k)\}\Re\{R_1(k)\}}{\Re\{R_1(k)\}\Re\{R_2(k)\} - \Im\{R_2(k)\}\Im\{R_1(k)\}}\right),$$

where T_{prf} is the time between two pulses, $R_1(k)$ is the complex lag k autocorrelation value for $r_1(k)$, and $R_2(k)$ is the complex lag k value for $r_2(k)$. From above,

$$\mathrm{vx} = \left(\frac{\lambda_x}{2\pi 2kT_{prf}}\right)\arctan\left(\frac{\Im\{R_1(k)\}\Re\{R_2(k)\} + \Im\{R_2(k)\}\Re\{R_1(k)\}}{\Re\{R_1(k)\}\Re\{R_2(k)\} - \Im\{R_2(k)\}\Im\{R_1(k)\}}\right).$$

[0035] Figure 6 illustrates an example method for employing the ultrasound imaging system.

[0036] It is to be understood that the following acts are provided for explanatory purposes and are not limiting. As such, one or more of the acts may be omitted, one or more acts may be added, one or more acts may occur in a different order (including simultaneously with another act), etc.

[0037] At 600, an ultrasound signal is transmitted into a field of view.

[0038] At 602, echoes, in response to the ultrasound signal, are received by a two dimensional transducer array.

[0039] At 604, the echoes are beamformed to produce a line along the depth direction z.

[0040] At 606, the echoes are beamformed to produce two lines, separated by a fixed angle, in the z-x plane.

[0041] At 608, the echoes are beamformed to produce two lines, separated by a fixed angle, in the z-y plane.

[0042] In this embodiment, acts 604-608 are performed concurrently and independently. However, it is to be appreciated that acts 604-608 do not have to be performed concurrently and independently.

[0043] At 610, vz is determined based on the line in the depth direction z, for example, using autocorrelation.

[0044] At 612, vx is determined based on the two lines in the z-x plane using the transverse oscillation approach.

[0045] At 614, vz is determined based on the two lines in the z-y plane using the transverse oscillation approach.

[0046] At 616, the velocities vz, vx and vy are visually presented. In one instance, this includes superimposing the data corresponding to the velocities vz, vx and vy over a B-mode or other image.

[0047] The methods described herein may be implemented via one or more processors executing one or more computer readable instructions encoded or embodied on computer readable storage medium such as physical memory which causes the one or more processors to carry out the various acts and/or other functions and/or acts. Additionally or alternatively, the one or more processors can execute instructions carried by transitory medium such as a signal or carrier wave.

[0048] Figure 7 schematically illustrates a variation of the embodiment of Figure 4. In this variation, only four (4) lines are beamformed instead of five (5). More specifically, the beamfomers 404 and 406 beamform respective lines, which the transverse velocity processor 414 processes, using a TO approach, to estimate vx, and the beamfomers 408 and 410 beamform respective lines, which the elevation velocity processor 416 processes, using a TO approach, to estimate vy. In this variation, the velocity processor 314 includes a depth velocity estimator 702, which estimates vz based on the two lines used to determine vx and/or the two lines used to determine vy. The beamformer 402 and/or the depth velocity processor 412 can be omitted. In another variation, the depth velocity processor 412 and the depth velocity estimator 702 are part of the same depth velocity component.

[0049] The application has been described with reference to various embodiments. Modifications and alterations will occur to others upon reading the application.

Claims

1. An ultrasound imaging system (300) comprising :

   a transducer array (302), including a two-dimensional array of transducer elements configured to transmit an ultrasound signal to traverse a field of view and to receive echoes from the field of view;
   transmit circuitry (304) configured to generate a set of pulses for the transducer array (302) so as to transmit the ultrasound signal to traverse the field of view;
   receive circuitry (306) configured to receive a two dimensional set of echoes produced in response to the ultrasound signal traversing structure in the field of view, the structure including flowing structure;
   a beamformer (312) configured to beamform the echoes to produce beamformed data therefrom; and
   a velocity processor (314) configured to process the beamformed data to determine velocity components therefrom;
   characterized in that the beamformer (312) is further configured to beamform four lines of data from the two dimensional set of echoes, the four lines of data including a first pair of lines and a second pair of lines;
   and **in that** the velocity processor (314) is configured to separately determine a transverse velocity component (vx) from the first pair of lines and an elevation velocity component (vy) from the second pair of lines derived from the same transmitted ultrasound signal and the same received set of two dimensional echoes, and to estimate a depth velocity component (vz) based on at least one of: the first pair of lines used to determine the transverse velocity component and the second pair of lines used to determine the elevation velocity component.

2. The system of claim 1, wherein the velocity processor (314) further includes:
   a transverse velocity processor (414) configured to determine the transverse velocity component (vx) based on the first pair of lines of data in the depth/transverse plane, the transverse velocity processor (414) determining the transverse velocity component based on a first transverse oscillation approach.

3. The system of claim 2, wherein velocity processor (314) further includes:
   an elevation velocity processor (416) configured to determine the elevation velocity component (vy) based on the second pair of lines of data in the depth/elevation plane, the elevation velocity processor (416) determining the elevation velocity component based on a second transverse oscillation approach.

4. The system of claim 2 or 3, wherein the pairs of two lines of data beamformed by the beamformer (312) include lines of data that are separated by a fixed receive angle.

5. The system of any one of claims 2 to 4, wherein sets of two lines beamformed by the beamformer (312) are separated by a quarter wavelength.

6. The system of claim 4 or 5, wherein the angle corresponds to an increasing lateral wavelength.

7. The system of any one of claims 2 to 6, wherein the velocity processor (314) further includes:
a depth velocity estimator (702) configured to estimate the depth velocity component based on at least one of: the pair of lines of data in at least one of the depth/transverse plane and the depth/elevation plane.

8. The system of any one of claims 1 to 7, wherein the depth velocity component represents velocity along a direction of the transmitted ultrasounds signal, the transverse velocity component represents velocity along a direction perpendicular to the direction of the depth velocity component, and the elevation velocity component represents velocity along a direction perpendicular to both the direction of the depth velocity component and the direction of the transverse velocity component.

9. The system of any one of claims 1 to 8, wherein the beamformer (312) is configured to beamform the first pair of lines in a z-x plane and separated by a first angle, and the second pair of lines in a z-y plane and separated by a second angle.

10. A method for determining velocity components from ultrasound echoes, the method comprising:

transmitting an ultrasound signal to traverse a field of view;
receiving a two dimensional set of received echoes produced in response to the transmitted ultrasound signal traversing structure in the field of view;
beamforming the received echoes to produce beamformed data therefrom; and
processing the beamformed data to determine velocity components therefrom;
characterized in that method further comprises:

beamforming four lines of data from the two dimensional set of received echoes, the four lines of data including a first pair of lines and a second pair of lines;
separately determining a transverse velocity component from the first pair of lines and an elevation velocity component from the second pair of lines; and
estimating a depth velocity component based on at least one of: the first pair of lines used to determine the transverse velocity component and the second pair of lines used to determine the elevation velocity component.

11. The method of claim 10, further comprising:

determining the transverse velocity component based on a first transverse oscillation approach, the transverse velocity component being based on the first pair of lines of data in a z-x plane; and
estimating the elevation velocity component based on a second transverse oscillation approach, the elevation velocity component being based on the second pair of lines of data in a z-y plane, the z-y plane being perpendicular to the z-x plane.

12. The method of claim 10, further comprising determining the transverse velocity component and the elevation velocity based on exactly four lines of data which include the pair of lines of data in the z-x plane and the pair of lines of data in the z-y plane.

Patentansprüche

1. Ein Ultraschallbildgebungssystem (300), umfassend:

ein Wandlerarray (302), einschließlich eines zweidimensionalen Arrays von Wandlerelementen, das konfiguriert ist, um ein Ultraschallsignal zu übertragen, um ein Sichtfeld zu durchqueren, und um Echos vom Sichtfeld zu empfangen;
eine Übertragungsschaltung (304), die konfiguriert ist, um einen Satz von Pulsen für das Wandlerarray (302) zu erzeugen, um das Ultraschallsignal zu übertragen, um das Sichtfeld zu durchqueren;
eine Empfangsschaltung (306), die konfiguriert ist, um einen zweidimensionalen Satz von Echos zu empfangen, die als Antwort auf die ultraschallsignaldurchquerende Struktur im Sichtfeld produziert werden, wobei die Struktur eine fließende Struktur einschließt;
einen Strahlformer (312), der konfiguriert ist, um die Echos strahlzuformen, um strahlgeformte Daten daraus zu produzieren; und

einen Geschwindigkeitsprozessor (314), der konfiguriert ist, um die strahlgeformten Daten zu verarbeiten, um daraus Geschwindigkeitskomponenten zu bestimmen;
dadurch gekennzeichnet, dass der Strahlformer (312) weiter konfiguriert ist, um vier Zeilen mit Daten von dem zweidimensionalen Satz von Echos strahlzuformen, wobei die vier Zeilen mit Daten ein erstes Paar von Zeilen und ein zweites Paar von Zeilen einschließen;
und dadurch, dass der Geschwindigkeitsprozessor (314) konfiguriert ist, um separat eine Transversalgeschwindigkeitskomponente (vx) vom ersten Paar von Zeilen und eine Höhengeschwindigkeitskomponente (vy) vom zweiten Paar von Zeilen zu bestimmen, abgeleitet von demselben übertragenen Ultraschallsignal und demselben empfangenen Satz von zweidimensionalen Echos, und um eine Tiefengeschwindigkeitskomponente (vz) zu schätzen, basierend auf mindestens einem von: dem ersten Paar von Zeilen, das verwendet wird, um die Transversalgeschwindigkeitskomponente zu bestimmen, und dem zweiten Paar von Zeilen, das verwendet wird, um die Höhengeschwindigkeitskomponente zu bestimmen.

2. Das System nach Anspruch 1, wobei der Geschwindigkeitsprozessor (314) weiter einschließt:
einen Transversalgeschwindigkeitsprozessor (414), der konfiguriert ist, um die Transversalgeschwindigkeitskomponente (vx) basierend auf dem ersten Paar von Zeilen mit Daten in der Tiefen-/Transversalebene zu bestimmen, wobei der Transversalgeschwindigkeitsprozessor (414) die Transversalgeschwindigkeitskomponente basierend auf einem ersten Transversaloszillationsansatz bestimmt.

3. Das System nach Anspruch 2, wobei der Geschwindigkeitsprozessor (314) weiter einschließt:
einen Höhengeschwindigkeitsprozessor (416), der konfiguriert ist, um die Höhengeschwindigkeitskomponente (vy) basierend auf dem zweiten Paar von Zeilen mit Daten in der Tiefen-/Höhenebene zu bestimmen, wobei der Höhengeschwindigkeitsprozessor (416) die Höhengeschwindigkeitskomponente basierend auf einem zweiten Transversaloszillationsansatz bestimmt.

4. Das System nach Anspruch 2 oder 3, wobei die Paare von zwei durch den Strahlformer (312) strahlgeformten Zeilen mit Daten Zeilen mit Daten einschließen, die durch einen festen Empfangswinkel getrennt sind.

5. Das System nach einem der Ansprüche 2 bis 4, wobei Sätze von zwei durch den Strahlformer (312) strahlgeformten Zeilen durch eine Viertelwellenlänge getrennt sind.

6. Das System nach Anspruch 4 oder 5, wobei der Winkel einer zunehmenden lateralen Wellenlänge entspricht.

7. Das System nach einem der Ansprüche 2 bis 6, wobei der Geschwindigkeitsprozessor (314) weiter einschließt:
einen Tiefengeschwindigkeitsschätzer (702), der konfiguriert ist, um eine Tiefengeschwindigkeitskomponente zu schätzen, basierend auf mindestens einem von: dem Paar von Zeilen mit Daten in mindestens einer von der Tiefen-/Transversalebene und der Tiefen-/Höhenebene.

8. Das System nach einem der Ansprüche 1 bis 7, wobei die Tiefengeschwindigkeitskomponente eine Geschwindigkeit entlang einer Richtung des übertragenen Ultraschallsignals darstellt, die Transversalgeschwindigkeitskomponente eine Geschwindigkeit entlang einer zur Richtung der Tiefengeschwindigkeitskomponente senkrechten Richtung darstellt und die Höhengeschwindigkeitskomponente eine Geschwindigkeit entlang einer zu beiden, zur Richtung der Tiefengeschwindigkeitskomponente und zur Richtung der Transversalgeschwindigkeitskomponente senkrechten Richtung darstellt.

9. Das System nach einem der Ansprüche 1 bis 8, wobei der Strahlformer (312) konfiguriert ist, um das erste Paar von Zeilen in einer z-x-Ebene und getrennt durch einen ersten Winkel und das zweite Paar von Zeilen in einer z-y-Ebene und getrennt durch einen zweiten Winkel strahlzuformen.

10. Ein verfahren zum Bestimmen von Geschwindigkeitskomponenten von Ultraschallechos, wobei das Verfahren umfasst:

Übertragen eines Ultraschallsignals, um ein Sichtfeld zu durchqueren;
Empfangen eines zweidimensionalen Satzes von empfangenen Echos, die als Antwort auf die übertragene ultraschallsignaldurchquerende Struktur im Sichtfeld produziert werden;
Strahlformen der empfangenen Echos, um daraus strahlgeformte Daten zu produzieren; und
Verarbeiten der strahlgeformten Daten, um daraus Geschwindigkeitskomponenten zu bestimmen;
dadurch gekennzeichnet, dass das Verfahren weiter umfasst:

Strahlformen von vier Zeilen mit Daten vom zweidimensionalen Satz von empfangenen Echos, wobei die vier Zeilen mit Daten ein erstes Paar von Zeilen und ein zweites Paar von Zeilen einschließen;
separates Bestimmen einer Transversalgeschwindigkeitskomponente vom ersten Paar von Zeilen und einer Höhengeschwindigkeitskomponente vom zweiten Paar von Zeilen; und
Schätzen einer Tiefengeschwindigkeitskomponente, basierend auf mindestens einem von: dem ersten Paar von Zeilen, das verwendet wird, um die Transversalgeschwindigkeitskomponente zu bestimmen, und dem zweiten Paar von Zeilen, das verwendet wird, um die Höhengeschwindigkeitskomponente zu bestimmen.

11. Das Verfahren nach Anspruch 10, weiter umfassend:

Bestimmen der Transversalgeschwindigkeitskomponente basierend auf einem ersten Transversaloszillationsansatz, wobei die Transversalgeschwindigkeitskomponente auf dem ersten Paar von Zeilen mit Daten in einer z-x-Ebene basiert; und
Schätzen der Höhengeschwindigkeitskomponente basierend auf einem zweiten Transversaloszillationsansatz, wobei die Höhengeschwindigkeitskomponente auf dem zweiten Paar von Zeilen mit Daten in einer z-y-Ebene basiert, wobei die z-y-Ebene senkrecht zur z-x-Ebene ist.

12. Das Verfahren nach Anspruch 10, weiter umfassend Bestimmen der Transversalgeschwindigkeitskomponente und der Höhengeschwindigkeit basierend auf genau vier Zeilen mit Daten, die das Paar von Zeilen mit Daten in der z-x-Ebene und das Paar von Zeilen mit Daten in der z-y-Ebene einschließen.

Revendications

1. Un système d'imagerie ultrasonore (300) comprenant :

une matrice de transducteurs (302), incluant une matrice bidimensionnelle d'éléments transducteurs configurée pour émettre un signal ultrasonore pour traverser un champ de vision et recevoir des échos en provenance du champ de vision ;
un ensemble de circuits d'émission (304) configuré pour générer un ensemble d'impulsions pour la matrice de transducteurs (302) de manière à émettre le signal ultrasonore pour traverser le champ de vision ;
un ensemble de circuits de réception (306) configuré pour recevoir un ensemble bidimensionnel d'échos produit en réponse à la structure traversant le signal ultrasonore dans le champ de vision, la structure incluant une structure en circulation ;
un dispositif de formation de faisceau (312) configuré pour former en faisceau les échos pour produire des données formées en faisceau à partir de ceux-ci ; et
un processeur de vitesse (314) configuré pour traiter les données formées en faisceau pour déterminer des composantes de vitesse à partir de celles-ci ;
caractérisé en ce que le dispositif de formation de faisceau (312) est en outre configuré pour former en faisceau quatre lignes de données à partir de l'ensemble bidimensionnel d'échos, les quatre lignes de données incluant une première paire de lignes et une seconde paire de lignes ;
et **en ce que** le processeur de vitesse (314) est configuré pour déterminer de manière séparée une composante de vitesse transversale (vx) à partir de la première paire de lignes et une composante de vitesse d'élévation (vy) à partir de la seconde paire de lignes résultant du même signal ultrasonore émis et du même ensemble reçu d'échos bidimensionnels, et pour estimer une composante de vitesse de profondeur (vz) sur la base d'au moins l'une de : la première paire de lignes utilisée pour déterminer la composante de vitesse transversale et la seconde paire de lignes utilisée pour déterminer la composante de vitesse d'élévation.

2. Le système selon la revendication 1, dans lequel le processeur de vitesse (314) inclut en outre :

un processeur de vitesse transversale (414) configuré pour déterminer la composante de vitesse transversale (vx) sur la base de la première paire de lignes de données dans le plan de profondeur/transversal,
le processeur de vitesse transversale (414) déterminant la composante de vitesse transversale sur la base d'une première approche d'oscillation transversale.

3. Le système selon la revendication 2, dans lequel le processeur de vitesse (314) inclut en outre :
un processeur de vitesse d'élévation (416) configuré pour déterminer la composante de vitesse d'élévation (vy) sur

la base de la seconde paire de lignes de données dans le plan de profondeur/élévation, le processeur de vitesse d'élévation (416) déterminant la composante de vitesse d'élévation sur la base d'une seconde approche d'oscillation transversale.

4. Le système selon la revendication 2 ou 3, dans lequel les paires de deux lignes de données formées en faisceau par le dispositif de formation de faisceau (312) incluent des lignes de données qui sont séparées par un angle de réception fixe.

5. Le système selon l'une quelconque des revendications 2 à 4, dans lequel les ensembles de deux lignes formées en faisceau par le dispositif de formation de faisceau (312) sont séparés par un quart de longueur d'onde.

6. Le système selon la revendication 4 ou 5, dans lequel l'angle correspond à une longueur d'onde latérale croissante.

7. Le système selon l'une quelconque des revendications 2 à 6, dans lequel le processeur de vitesse (314) inclut en outre :
un estimateur de vitesse de profondeur (702) configuré pour estimer la composante de vitesse de profondeur sur la base d'au moins l'une de : la paire de lignes de données dans au moins l'un du plan de profondeur/transversal et du plan de profondeur/d'élévation.

8. Le système selon l'une quelconque des revendications 1 à 7, dans lequel la composante de vitesse de profondeur représente la vitesse le long d'une direction du signal ultrasonore émis, la composante de vitesse transversale représente la vitesse le long d'une direction perpendiculaire à la direction de la composante de vitesse de profondeur, et la composante de vitesse d'élévation représente la vitesse le long d'une direction perpendiculaire à la fois à la direction de la composante de vitesse de profondeur et à la direction de la composante de vitesse transversale.

9. Le système selon l'une quelconque des revendications 1 à 8, dans lequel le dispositif de formation de faisceau (312) est configuré pour former en faisceau la première paire de lignes dans un plan z-x et séparées par un premier angle, et la seconde paire de lignes dans un plan z-y et séparées par un second angle.

10. Un procédé pour déterminer des composantes de vitesse à partir d'échos ultrasonores, le procédé comprenant :

l'émission d'un signal ultrasonore pour traverser un champ de vision ;
la réception d'un ensemble bidimensionnel d'échos reçus produits en réponse à la structure traversant la signal ultrasonore émis dans le champ de vision ;
la formation en faisceau des échos reçus pour produire des données formées en faisceau à partir de ceux-ci ; et
le traitement des données formées en faisceau pour déterminer des composantes de vitesse à partir de celles-ci ;
caractérisé en ce que le procédé comprend en outre :

la formation en faisceau de quatre lignes de données à partir de l'ensemble bidimensionnel d'échos reçus, les quatre lignes de données incluant une première paire de lignes et une seconde paire de lignes ;
la détermination de manière séparée d'une composante de vitesse transversale à partir de la première paire de lignes et d'une composante de vitesse d'élévation à partir de la seconde paire de lignes ; et
l'estimation d'une composante de vitesse de profondeur sur la base d'au moins l'une de : la première paire de lignes utilisée pour déterminer la composante de vitesse transversale et la seconde paire de lignes utilisée pour déterminer la composante de vitesse d'élévation.

11. Le procédé selon la revendication 10, comprenant en outre :

la détermination de la composante de vitesse transversale sur la base d'une première approche d'oscillation transversale, la composante de vitesse transversale étant basée sur la première paire de lignes de données dans un plan z-x ; et
l'estimation de la composante de vitesse d'élévation sur la base d'une seconde approche d'oscillation transversale, la composante de vitesse d'élévation étant basée sur la seconde paire de lignes de données dans un plan z-y, le plan z-y étant perpendiculaire au plan z-x.

12. Le procédé selon la revendication 10, comprenant en outre la détermination d'une composante de vitesse transversale et de la vitesse d'élévation sur la base d'exactement quatre lignes de données qui incluent la paire de lignes de données dans le plan z-x et la paire de lignes de données dans le plan z-y.

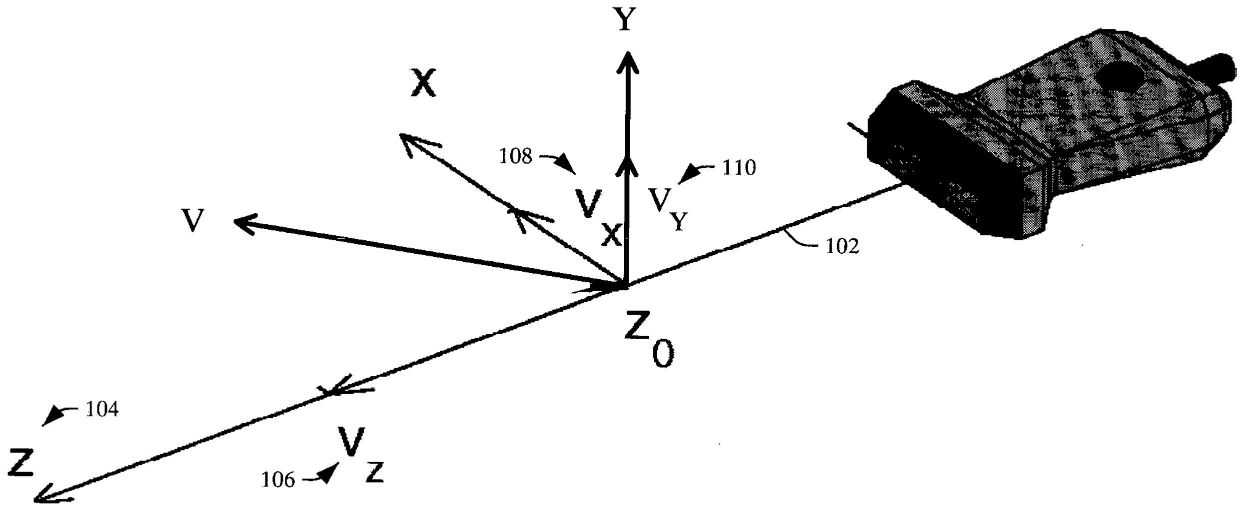

FIGURE 1
(PRIOR ART)

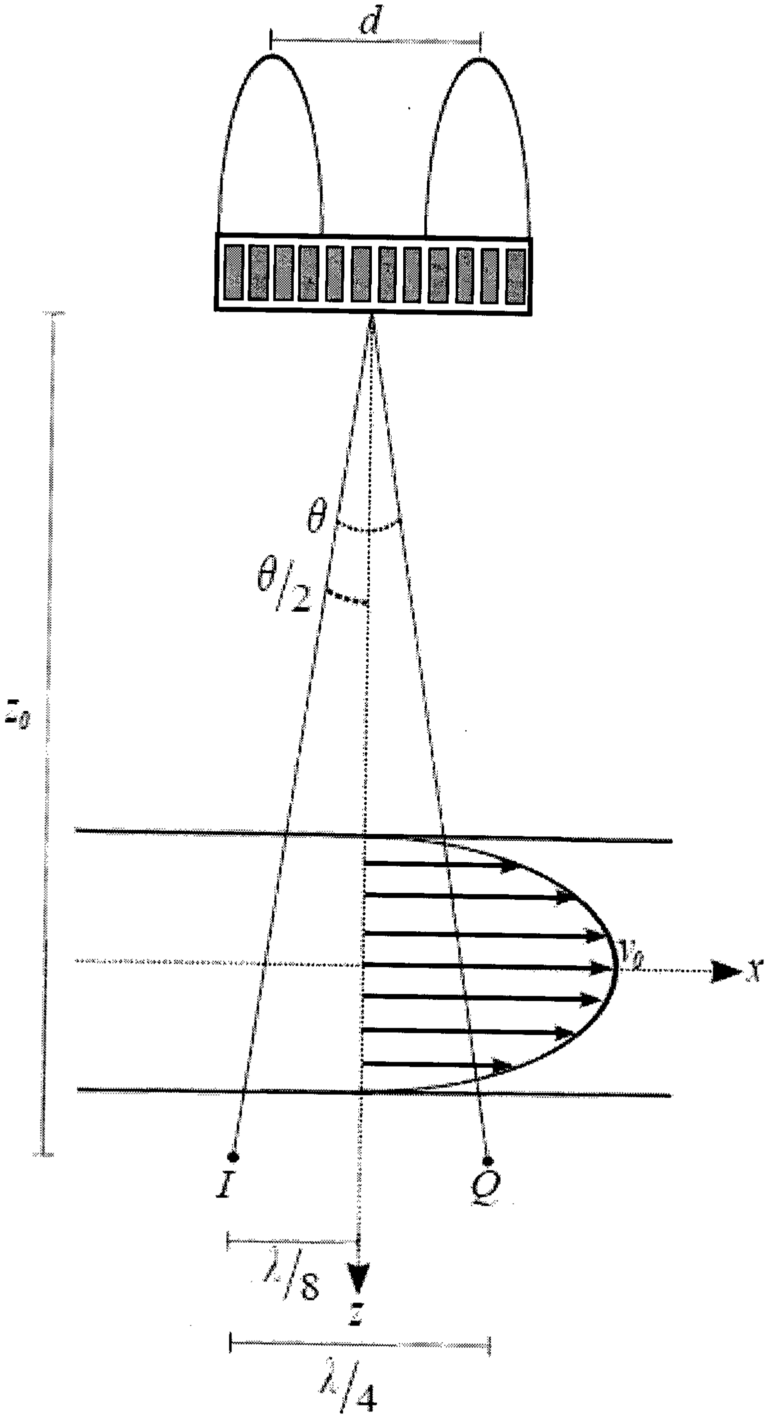

FIGURE 2
(PRIOR ART)

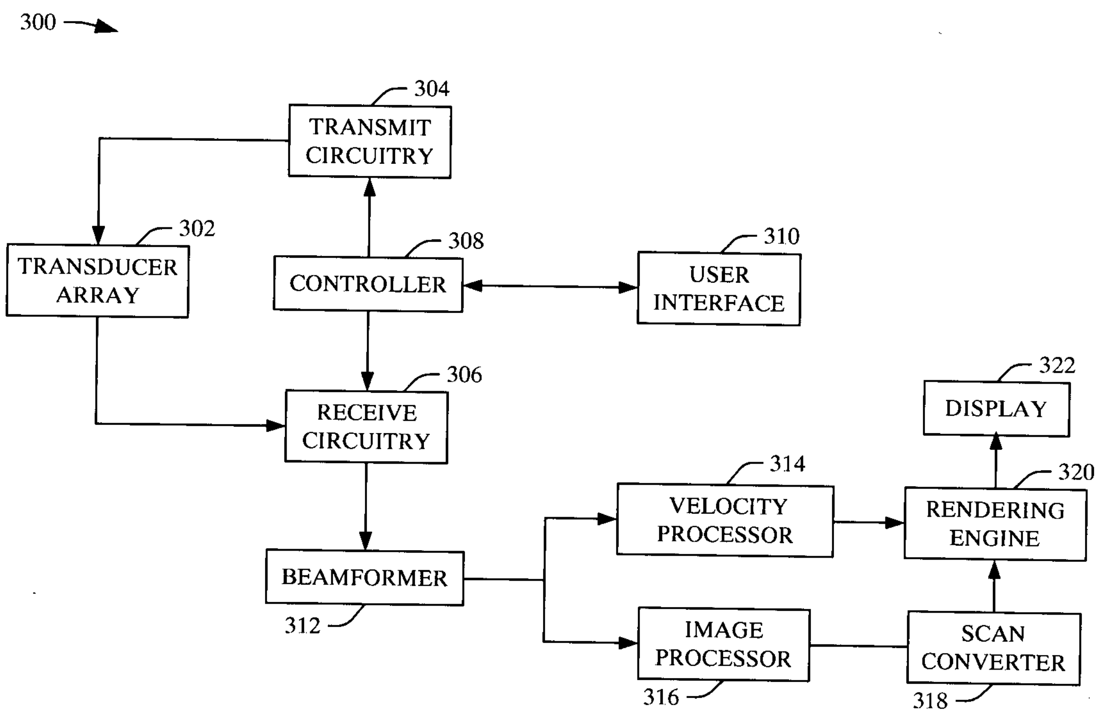
300
TRANSMIT CIRCUITRY
304
TRANSDUCER ARRAY
302
CONTROLLER
308
USER INTERFACE
310
RECEIVE CIRCUITRY
306
DISPLAY
322
VELOCITY PROCESSOR
314
RENDERING ENGINE
320
BEAMFORMER
312
IMAGE PROCESSOR
316
SCAN CONVERTER
318

FIGURE 3

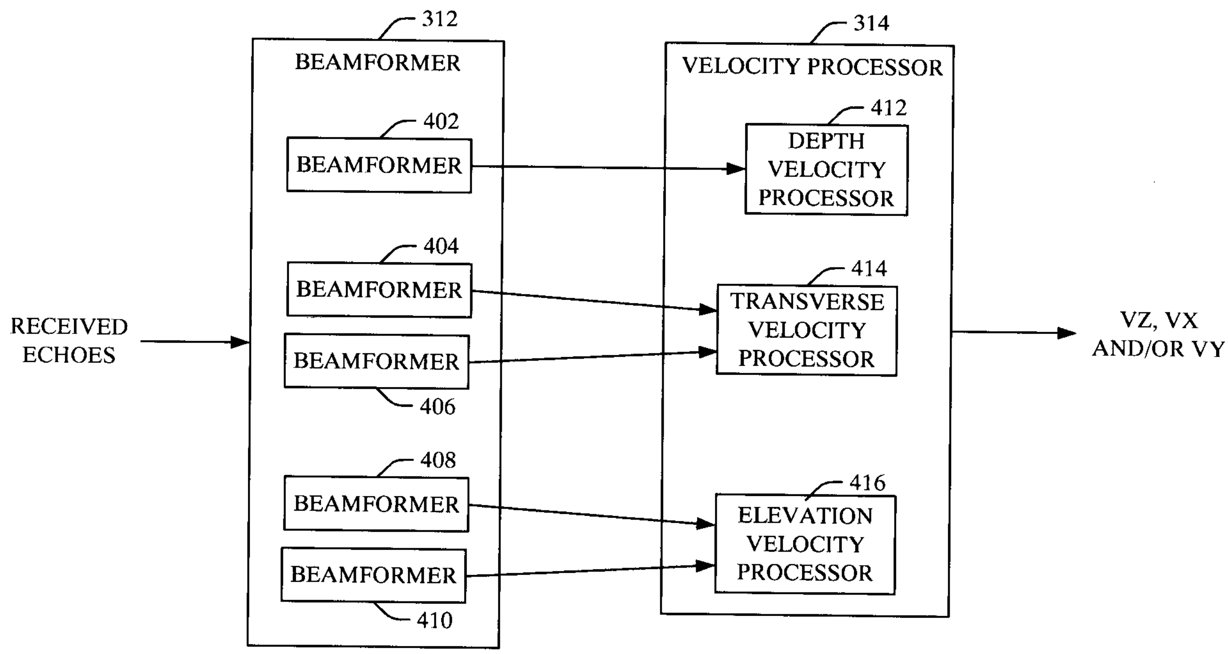
312
BEAMFORMER
402
BEAMFORMER
404
BEAMFORMER
BEAMFORMER
406
408
BEAMFORMER
BEAMFORMER
410
314
VELOCITY PROCESSOR
412
DEPTH VELOCITY PROCESSOR
414
TRANSVERSE VELOCITY PROCESSOR
416
ELEVATION VELOCITY PROCESSOR
RECEIVED ECHOES
VZ, VX AND/OR VY

FIGURE 4

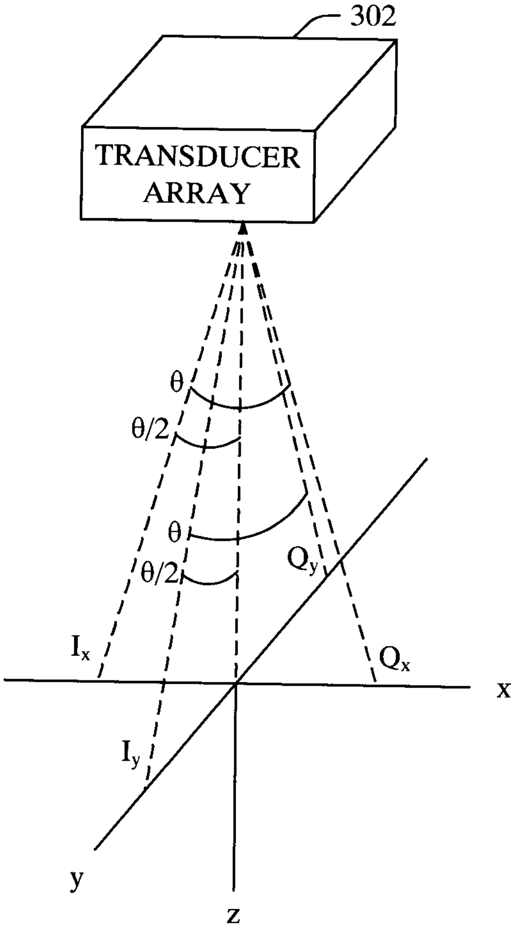

FIGURE 5

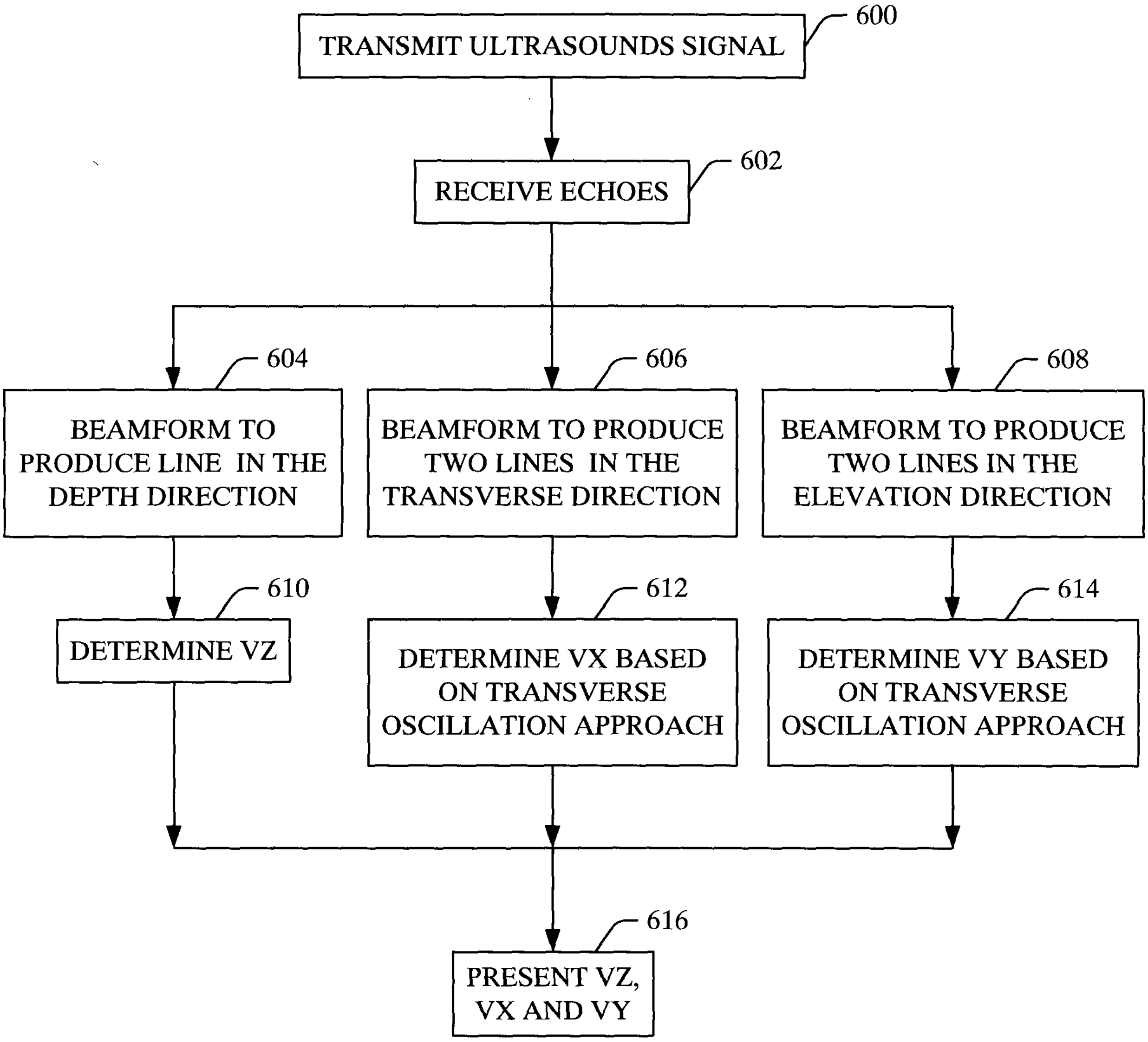
TRANSMIT ULTRASOUNDS SIGNAL
600
RECEIVE ECHOES
602
BEAMFORM TO PRODUCE LINE IN THE DEPTH DIRECTION
604
BEAMFORM TO PRODUCE TWO LINES IN THE TRANSVERSE DIRECTION
606
BEAMFORM TO PRODUCE TWO LINES IN THE ELEVATION DIRECTION
608
DETERMINE VZ
610
DETERMINE VX BASED ON TRANSVERSE OSCILLATION APPROACH
612
DETERMINE VY BASED ON TRANSVERSE OSCILLATION APPROACH
614
PRESENT VZ, VX AND VY
616

FIGURE 6

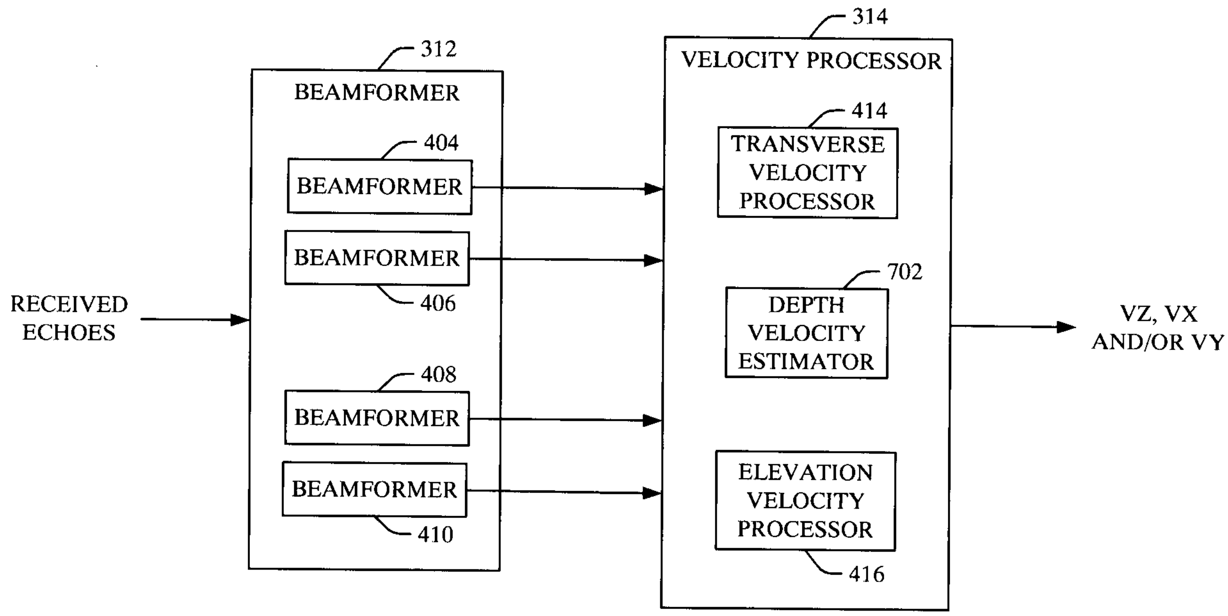
RECEIVED
ECHOES
312
BEAMFORMER
404
BEAMFORMER
BEAMFORMER
406
408
BEAMFORMER
BEAMFORMER
410
314
VELOCITY PROCESSOR
414
TRANSVERSE
VELOCITY
PROCESSOR
702
DEPTH
VELOCITY
ESTIMATOR
ELEVATION
VELOCITY
PROCESSOR
416
VZ, VX
AND/OR VY

FIGURE 7

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	三维（3D）横向振荡矢量速度超声成像		
公开(公告)号	EP2766738B1	公开(公告)日	2019-08-21
申请号	EP2011782214	申请日	2011-10-11
[标]申请(专利权)人(译)	B-K医疗公司		
申请(专利权)人(译)	B-ķ医疗APS		
当前申请(专利权)人(译)	B-ķ医疗APS		
[标]发明人	JENSEN JORGEN ARENDT PIHL MICHAEL JOHANNES		
发明人	JENSEN, JORGEN, ARENDT PIHL, MICHAEL, JOHANNES		
IPC分类号	G01P5/24 G01S15/58 G01S15/89 A61B8/06		
CPC分类号	A61B8/06 G01P5/244 G01S15/8984 G01S15/8993 A61B8/145 A61B8/4488 A61B8/463 A61B8/5223		
其他公开文献	EP2766738A1		
外部链接	Espacenet		

摘要(译)

超声成像系统（300）包括换能器阵列（302），其具有被配置为发送超声信号和接收回波的二维换能器元件阵列，被配置为控制换能器阵列以发送超声信号的发送电路（304）。为了遍历视场，接收电路（306），其被配置为接收响应于视场中的超声信号穿越结构而产生的二维回波组，其中该结构包括流动结构。一种被配置为对回波进行波束形成的波束形成器（312），以及被配置为分别确定深度速度分量，横向速度分量和高度速度分量的速度处理器（314），其中，基于相同的发送的超声信号来确定速度分量。和相同的接收的二维回波组。

$$VX=\left(\frac{\lambda_x}{2\pi 2kT_{prf}}\right)\arctan\left(\frac{\Im\{R_1(k)\}\Re\{R_2(k)\}+\Im\{R_2(k)\}\Re\{R_1(k)\}}{\Re\{R_1(k)\}\Re\{R_2(k)\}-\Im\{R_2(k)\}\Im\{R_1(k)\}}\right),$$